Electroweak Symmetry Breaking Working Group Summary Part II : Experiment

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Workshop Structure (experiment)

- Global Fit of Electroweak Precision Measurements
  - LEP-I, SLC, LEP-II, Tevatron-I, nuTeV, ... (Robert Clare)
- Overview of Collider Experiments
  - Tevatron (Elvira, McNamara, Wang, Watts)
  - LHC (Marcus Schumacher)
  - LC (Aurelio Juste)
  - Testing Higgs potentials with hadron & e^+e^- colliders (Albert DeRoeck)
- **Discussion Sessions**
  - Tevatron centric - the only running collider for EWSB
  - What is the real capability of Tevatron Run II for EWSB?
  - Tevatron-LHC Connection
    - How could Tevatron help prepare LHC physics?
  - Contributed talks (targeted for young physicists)
    - 8 experiment abstracts - 5 given at this workshop
    - 4 theory abstracts - 4 given at this workshop

LHC SM Higgs (recent improvements)

- SM Higgs Discovery
  - New channels for low M_H (proposed by Rainwater, Zeppenfeld et al.)
  - Vector Boson Fusion
    - Higgs -> $\tau^+\tau^-$, W^+W^-, invisible
    - largely increase discovery potential
    - allow to measure Higgs couplings
    - good for invisible decays
      » Br(invisible) limit ~20%

Status 2001

Status now
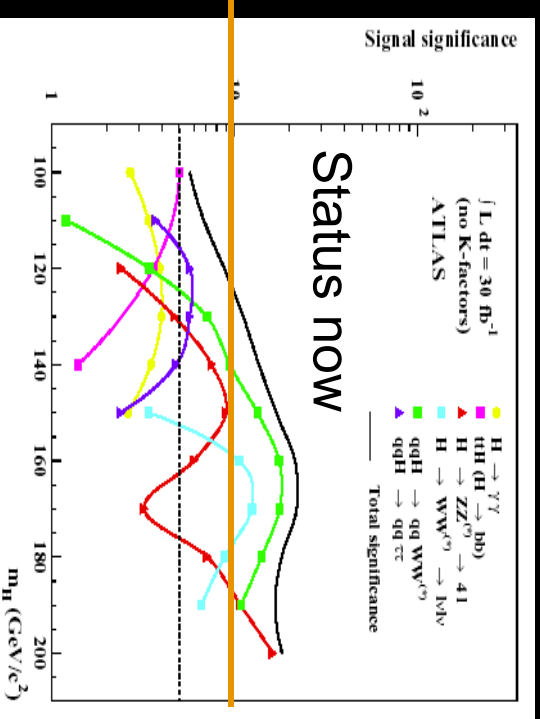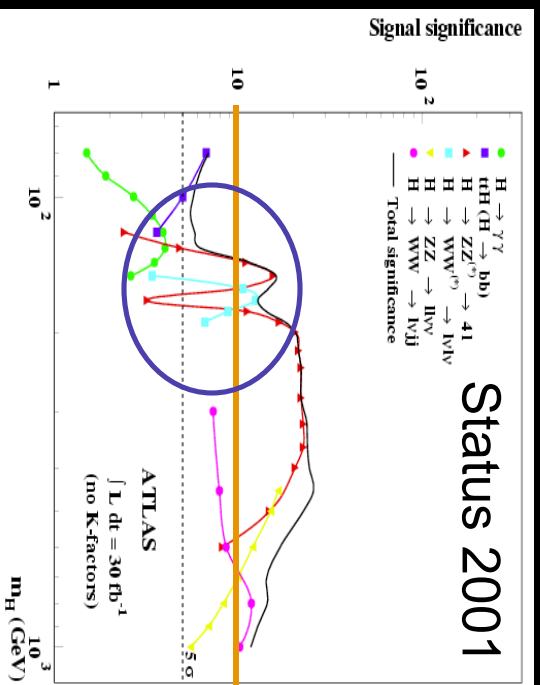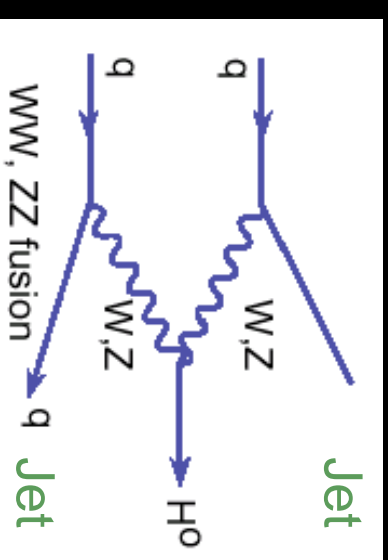
LHC SM Higgs (recent improvements)

– Dominant backgrounds

• e.g. H $\rightarrow$ $\tau\tau$

Z jj (EW)

Z jj (QCD)
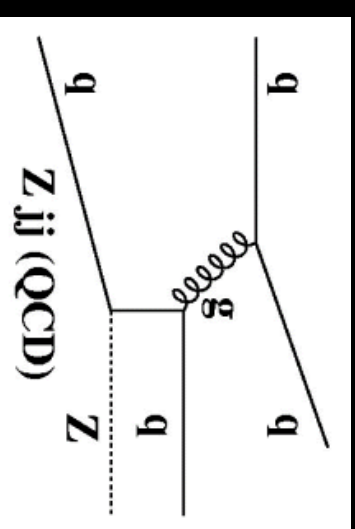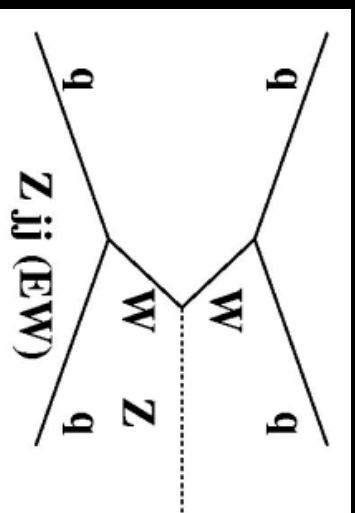
– To be done: reinvestigate discovery potential with

• NLO MC

• Improved matching ME + parton shower (Herwig/Pythia)

• Tevatron can play a role in evaluating NLO calculations, ME + parton shower matching, etc. using W + 2-jets

– Tevatron-LHC connection

Updated LHC MSSM Scan

- Recent Improvements
  - New calculations for masses and branching ratios
  - New channels added, in particular VBF channels
  - New benchmark scenarios considered
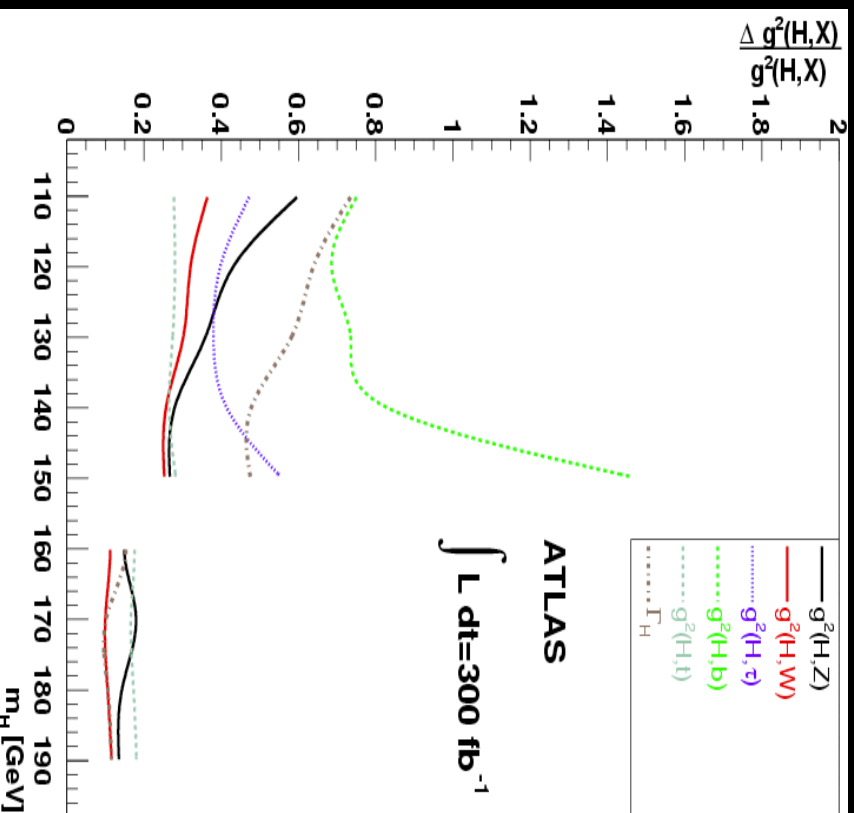- maximal mixing, no mixing, gluophobic, small α scenarios

MHMAX scenario 300 fb^{-1}

$\tan\beta$

10

1

100 200 300 400 500 600 700 800 900 1000

M_A (GeV)

h,H,A,H^{+-}

h,H,A

h only

h,H,A

Excluded by LEP
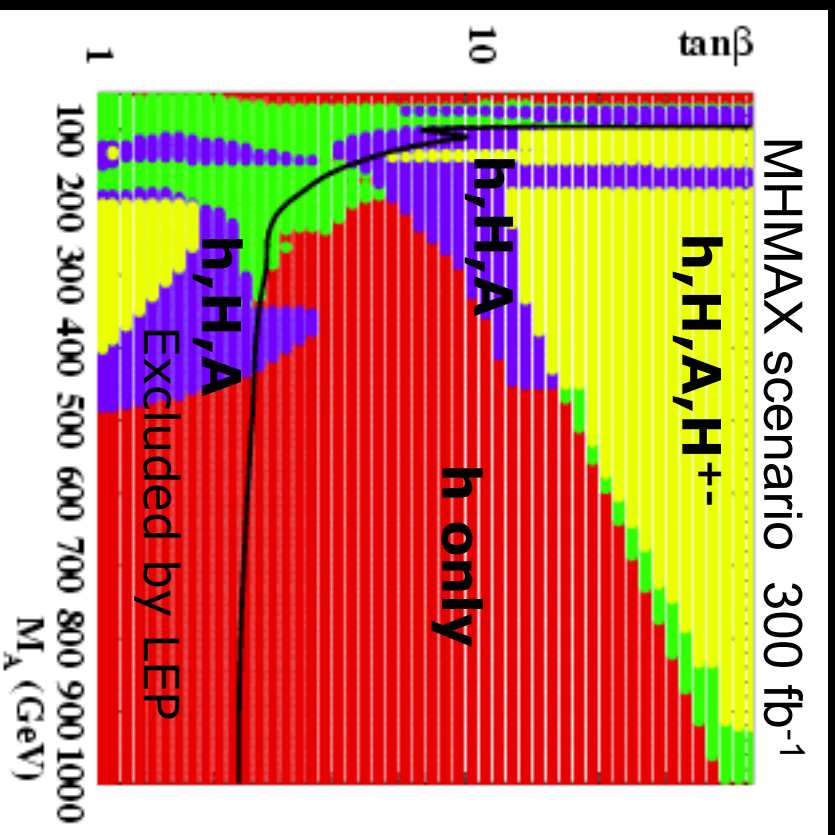
No holes !
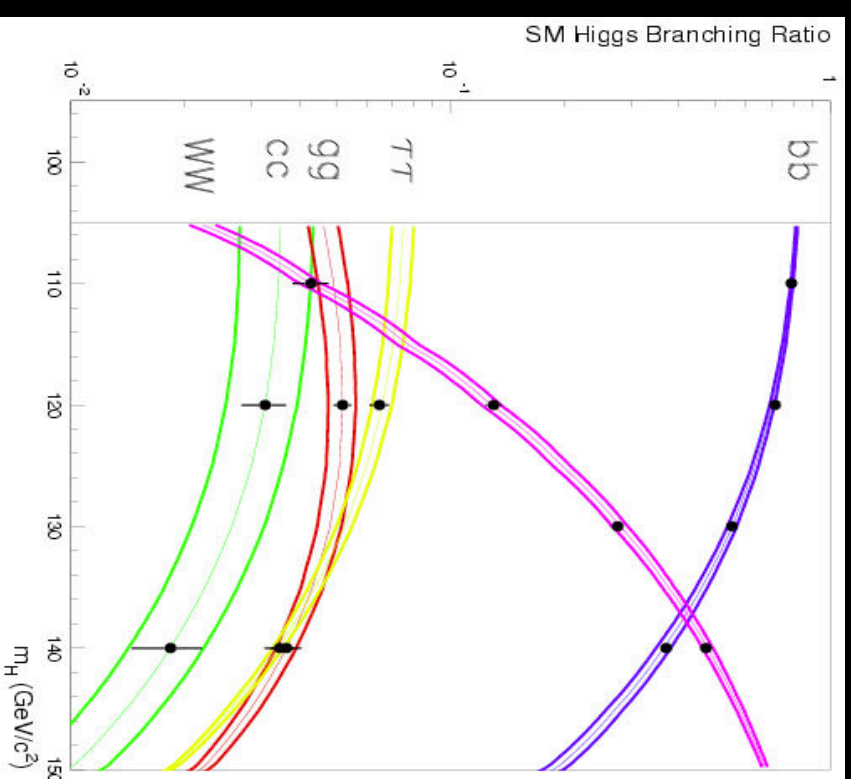
(also in 3 other benchmark scenarios)

Higgs Couplings: LHC & LC

LHC:
~3 years of high lum running

Duhrssen, ATL-PHYS-2003-030

e+e- LC:
√s = 350 GeV, L = 500 fb⁻¹

Battaglia, Desch, hep-ph/0101165
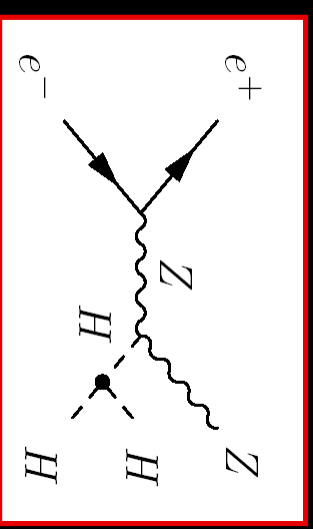
Testing the Higgs Potential

- Determination of the shape of the Higgs potential
  - needed for the complete investigation of the Higgs profile and to obtain a direct proof of the mechanism of EW symmetry breaking
  - Tests may reveal the extended nature of the Higgs sector.
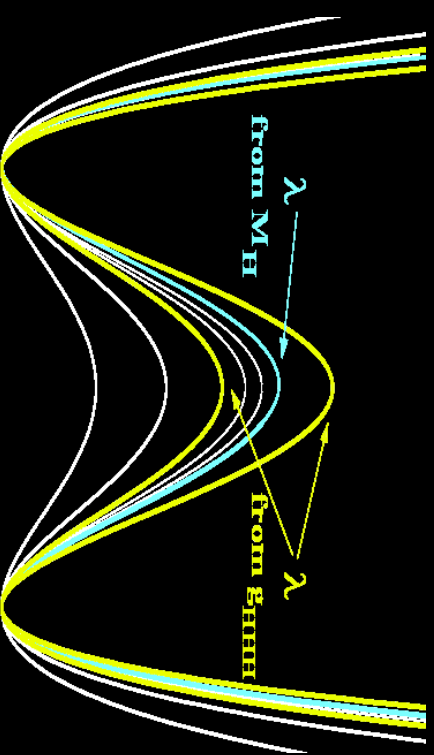
- Access via Higgs self coupling

$$V_H = \frac{m_H^2}{2} H^2 + \frac{m_H^2}{2v} H^3 + \frac{m_H^4}{8v^2} H^4$$
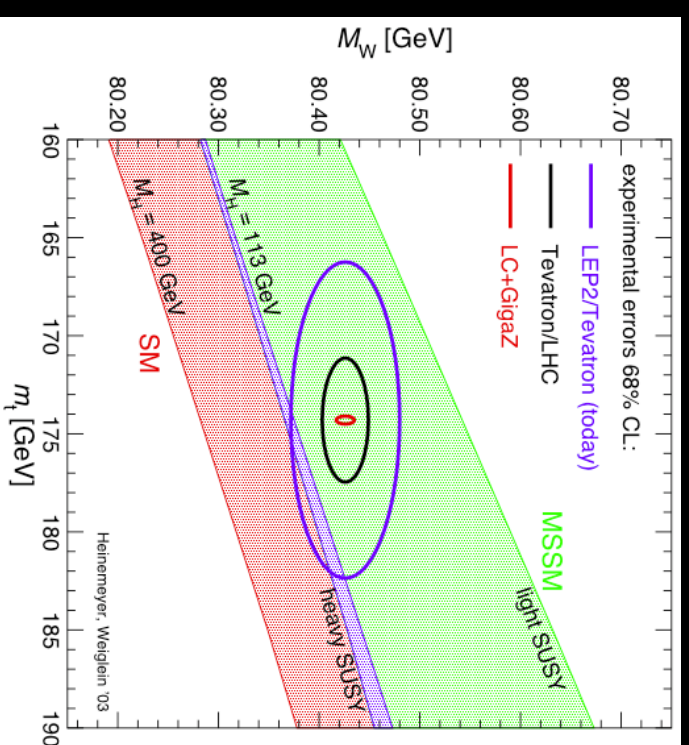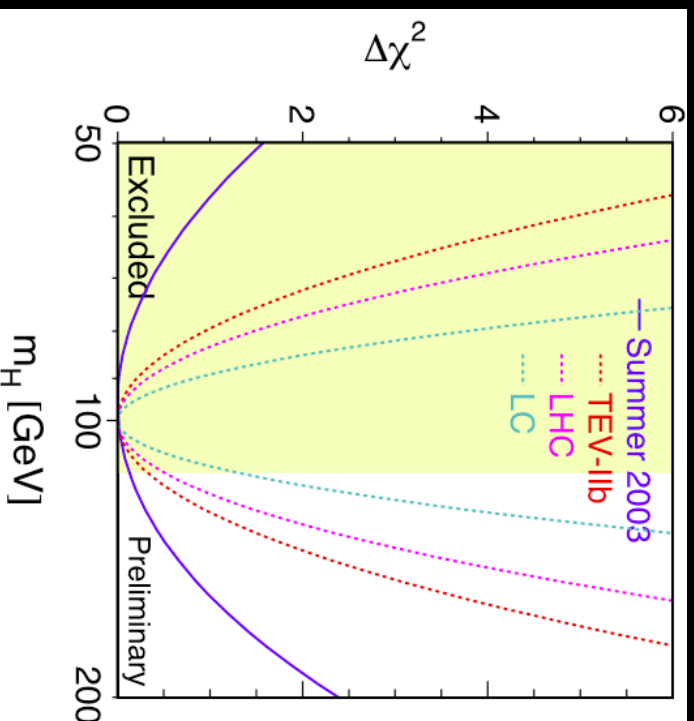
Testing the Higgs Potential

- ## Hadron Colliders
  - LHC will have a hard time to measure.
    - Can possibly establish that $\lambda_{HHH} \neq 0$ if $150 < M_H < 200$ GeV
  - SLHC (luminosity upgraded LHC) can measure λ_{HHH} to
    - 20-30% if $150 < M_H < 200$ GeV, 50-80% if $120 < M_H < 140$ GeV.
  - VLHC can measure λ_{HHH} to
    - 4-15% if $140 < M_H < 200$ GeV, 20-40% if $120 < M_H < 140$ GeV.

- ## Lepton Colliders
  - LC (0.5 - 1 TeV) can measure λ_{HHH} to 20-35% if $M_H < 140$ GeV.
  - CLIC (1 - 5 TeV) can measure λ_{HHH} to 7-15% if $M_H < 240$ GeV.
  - LC results can improve by factor up to 1.3-1.7 with polarized beam.

EWK Precision Measurements

- Testing models, building models
  - Current measurements
    - Most of technicolor models are disfavored.
    - Exclude the Little Higgs model with new physics scale < 3-4 TeV.
  - Future
    - Further constraining models/theories (with discoveries)

$\Delta\chi^2$

Excluded

Preliminary

—— Summer 2003
······ TEV-IIb
- - - LHC
····· LC

m_H [GeV]

M_W [GeV]

experimental errors 68% CL:
—— LEP2/Tevatron (today)
—— Tevatron/LHC
—— LC+GigaZ

$M_H = 400$ GeV
$M_H = 113$ GeV
SM
MSSM
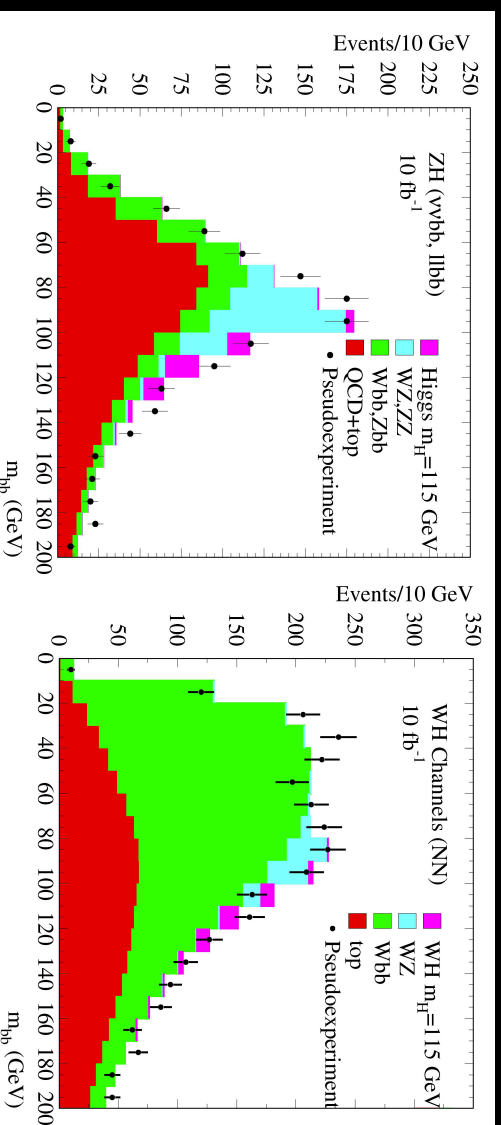light SUSY
heavy SUSY

m_t [GeV]

Heinemeyer, Weiglein '03

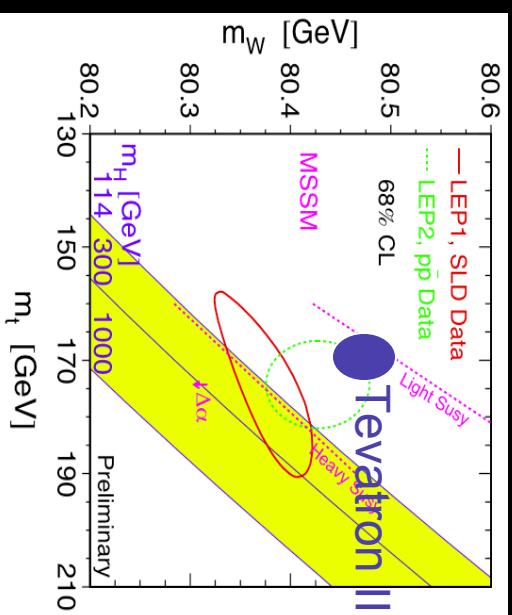# Tevatron EWSB Capability (1)

- What is the real capability of Tevatron Run II to study EWSB?

- EWK precesion measurements
  - ($\delta M_{top} \sim 2$GeV) provides important information to some model builders.

- SM Higgs Discoveries:
  - Discovering the SM Higgs is the hardest.
  - $M_H > \sim 120$ GeV @95% CL
  - 115 GeV Higgs → From WH, ZH Production (10 fb^{-1})

Tevatron EWSB Capability (2)

- MSSM (sparticle masses ~ 1 TeV, maximal stop mixing)
  - Exclude the entire para. space with 5 fb^{-1}.
- Other new things
  - MSSM
  - NMSSM
  - Dynamical EWSB
  - GUT-inspired models (eg. Light Higgs triplet)
  - ExtraD-EWSB
  - CP violation in Higgs sector
  - Others

- Studies done in some cases, but we need to make one coherent document.
- Further studies to be done in some other cases (Tevatron, LHC)
  - NMSSM
  - Little Higgs
  - Radion -> $\gamma\gamma$ (ED)
  - CP violation in Higgs sector
  - 3 b-jets at Tevatron
  - Fermiphobic scenario at Tevatron
  - We have assigned tasks to individuals.

We will make one document in a couple of months.

Tevatron - LHC Connection

- How can the Tevatron help prepare LHC physics?
  - Led by Dieter Zeppenfeld and Bruce Mellado
  - Higgs search at LHC needs reliable background simulations.
  - Tevatron can provide important information for
    - tuning parton and particle level Monte Carlos
    - Matrix Element calculations interfaced with Pythia/Herwig
  - Tevatron experience
    - M_{top} and top properties (U.K. Yang, F. Canelli)
    - Heavy gauge boson searches (Y.S. Chung)
    - Single top searches: V_{tb} (C. Ciobanu)
    - ME + parton shower matching, etc. (Steve Mrenna)
  - Young physicists at Tevatron will contribute tremendously to LHC physics.

We will make one document in a couple of months.
(S. Mrenna et al.)

Concluding Remarks

- It has been a very useful workshop.
  - enough discussions
- We initiated two documents
  - expected in a couple of months
  - useful information to
    - Tevatron physicists
    - LHC physicists
    - DoE/NSF funding agencies
- Many thanks to the organizers for this wonderful workshop.